KEPCO POWER SUPPLY news

Latest information on the development and application of Voltage/Current Regulated Power Supplies.

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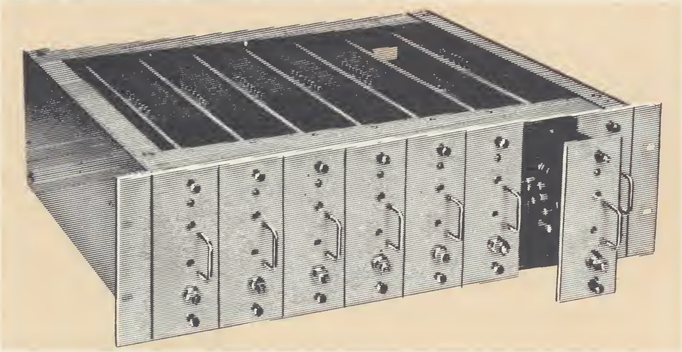
VOLUME 9 – NUMBER 146-1147

THE NEW "KG" ISOLATED MODULAR POWER SUPPLY

by JOSEPH R. GATLEY, Sr. Design Engineer

Model KG 25-0.2 was designed and developed to fill the need for a super-regulated isolated modular power supply of Kepco quality. Its voltage and current range of 0-25 volts at 0-0.2 amperes was selected to cover the requirements of most transducer applications. The package is designed for convenient eight-in-a-row rack mounting (5¼″ high) to match multiunit installations common in transducer system installations.



Batteries have long been used as isolated power sources in critical applications, but the obvious drawbacks of aging, drift and replacement nuisance, plus the lack of adjustment and means of remote error sensing have caused a shift to more sophisticated hardware.

In order to achieve the required accuracy with modern bridge measurement systems, unusual demands are made on the power supplies. The ideal source for such applications has been described as a zero-impedance battery, suspended in free space. While this ideal will never be realized, a close approximation has been attained in the new Kepco Model KG 25-0.2 Power Source.

The isolation capacitance from output to AC input is called C_x, and is less than 1.0 picofarad in this new model. Capacitance between DC output and ground (Cg) is held to less than 200 picofarads, with a parallel resistance greater than 10,000 megohms. The importance of these parameters will be illustrated in an example given further on.

Regulation, the variation of output versus line and load parameters, is also extremely important in transducer applications. The regulation of Model KG 25-0.2 power supply has been conservatively designed for less than 0.001% output voltage change versus line voltage variation of 105-125V AC, and less than 0.005% output voltage change (or 0.5 mv, whichever is greater) for a load change of 0-200 ma. These specs are typically conservative, and allow a wide margin of safety. Temperature coefficient, another very important parameter, has been given a great deal of attention in this model, to reduce its contribution to variation in output to less than 0.005% per °C. Eight hour stability, the "residual" drift at constant line, load and temperature, is less than 0.005% (or 1.0 mv, whichever is greater).

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ISOLATION TRANSFORMER FOR STRAIN GAUGE POWER SUPPLY

by ARTHUR ROSIN *and* FRANKLIN ROSENBUSCH,
Kepco Magnetics Division

A power supply for strain gauge operation, imposes a number of unusual requirements on the transformer which powers it. A companion article in this issue of the *Kepco Power Supply News*, "The New KG Modular Power Supply", develops in detail the necessity for minimizing AC line leak-through and maximizing common mode rejection.

Translated into transformer terminology the critical parameters may be summarized as follows:

1. The effective input-to-output capacitance (C_X) is to be less than 1.0 pf.
2. Capacitance (Cg) between transformer secondary and ground is to be less than 100 pf, and the parallel leakage resistance (Rg) is to be much greater than 10,000 megohms.
3. Pickup of stray AC fields by the transformer secondary, or subsequent circuitry, is to be minimized.

This article will outline the techniques employed to realize the desired specifications.

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SHOW VAN USED BY NACO ELECTRONICS CORP.

The NACO Electronics Corp., Kepco's upstate New York State sales representatives cover a great deal of territory with their sales demonstration van. This brings to Kepco customers first hand demonstrations and visual inspection of Kepco regulated power supplies. The following tells their story:

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in this issue..

THE NEW "KG" ISOLATED MODULAR POWER SUPPLY

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Tight regulation such as this is achieved through the use of new and improved circuitry which maintains extremely close control of *all* critical voltages and currents internal to the unit. The all-silicon circuit includes *four* temperature-compensated zener diodes, *all* with operating currents rigidly pegged to their optimum values. High internal gain and high quality low noise circuit components reduce the residual output ripple and noise voltage to less than 100 microvolts rms.

A ten-turn locking voltage control, mounted on the front panel, provides a voltage adjustment resolution to better than 0.02% (5 millivolts). A very sharp current-limit adjust, also accessible from the front, can be set to limit short-circuit current as close as 20 ma above working load current, thus providing a high degree of protection for external circuitry.

The current limit is *not* affected by accidental opening of the error sensing leads.

Output impedance is very low (6 milliohms at DC) and negligible at higher frequencies when compared to the impedance of the connecting wires usually necessary in measurements applications.

Error sensing terminals are provided to reduce the DC losses in the load wires to virtually zero by including these leads in the feedback loop. Up to 0.5 volt drop per lead can be tolerated, with no voltage derating of the unit. In practice, this means each load wire can be 250 feet of #20AWG, or 620 feet of #16AWG, etc., at the full 200 ma output. At lighter loads, of course, longer wires or smaller gauges may be used. Clamping diodes are incorporated in the unit to limit voltage excursion if the error sensing leads are broken or inadvertently disconnected.

in the input transformer, so there are no AC leads whatsoever on the front panel. (There is no AC switch and the pilot lamp is DC operated.)

Of the component parts, the most severe requirements are imposed on the input transformer, supplied by Kepco Magnetics, Inc. The design considerations for this special transformer are described in detail elsewhere. The isolation capabilities of the Model KG 25-0.2 are closely linked to the characteristics of this component.

Applications for *isolated* or *guarded* DC power supplies range from field civil engineering, to the laboratories of medical electronics. In fact, such supplies find use in any branch of science or engineering where precise measurements, free from spurious indicattions, are required.

Resistive bridge transducers especially require a clean, free-floating source of DC voltage; so do the free-floating amplifiers which boost their minute signals. Since the isolation of such an amplifier is no better than its power supply, the need for a well isolated source is obvious.

A simplified diagram for one typical application is shown in Figure 1. It shows a Model KG 25-0.2 connected as the energizing source for a strain gauge bridge. The transducer is shown grounded at its point of measurement (the usual case). The supply ground and AC line (earth) ground are shown separately in order to illustrate the fact that substantial potentials can and do exist between widely separated ground points. (A fact painfully evident to workers with microvolt signals.)

The stray impedances in the power supply, although actually distributed effects, are shown as lumped constants: C_x, the input-to-output effective capacitance; Cg, the output-to-ground capacitance; and Rg, the isolation resistance to ground.

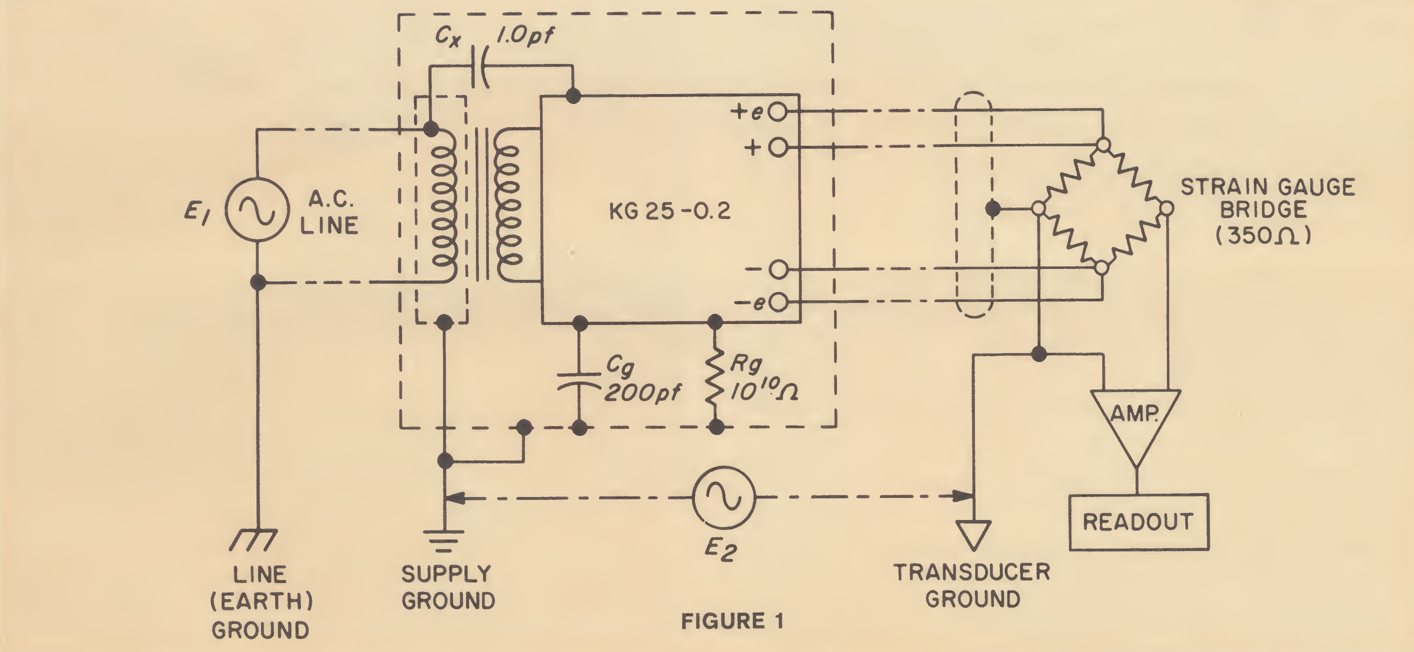

FIGURE 1

The very high values of isolation impedance achieved in this unit are made possible by careful selection of materials and components, plus the utmost care in circuit layout. The enire circuit is mounted on a glass laminate circuit board, with a nonmetallic front panel. All AC leads are separated as far as possible from sensitive DC control circuitry. The AC fuse is on the rear, mounted

The manner in which these impedances affect the transducer signal is as follows—worst case conditions being imposed throughout:

$$C_x = 1.0 \text{ pf}, C_g = 200 \text{ pf}, R_g = 10{,}000 \text{ megohms}.$$

C_x presents reactance to the line voltage equal to $\frac{1}{\omega C}$.

At 60 Hz. this is

$$\frac{1}{(6.28)(60)(10^{-12})} = 2.65 \times 10^{9} \text{ ohms}$$

For a 120 volt input, an AC leakage current of

$$\frac{120}{2.65 \times 10^{9}} = 4.52 \times 10^{-8}$$

amperes will flow. This current, returning through a typical 350 ohm bridge, will generate a voltage equal to $(4.52 \times 10^{-8} \times 350)$ volts or 15.8 microvolts (rms). This voltage of course, will only appear in the transducer output as a percentage proportional to the bridge unbalance, e.g., with a 1% unbalance, the AC ripple or noise voltage attributable to C_X at the bridge output would be approximately 0.16 microvolt rms, or 0.45 microvolt peak-to-peak.

Cg offers a reactance to the common-mode voltage of E_2 of

$$\frac{1}{(6.28)(60)(2 \times 10^{-10})} = 1.33 \times 10^{7} \text{ ohms.}$$

The paralleled resistance, Rg, of at least 10^{10} ohms, being nearly three orders of magnitude greater, has a negligible effect on the absolute magnitude of the impedance. The ripple and noise introduced in the bridge output through this impedance by the common-mode voltage E_2 is, of course, directly proportional to the magnitude of E_2, but if we assume E_2 to be 1.0 volt rms, then a current through Cg and Rg in parallel will be

$$\frac{E_2}{/Z/} = \frac{1.0}{1.33 \times 10^{7}} = 0.075 \text{ microamperes.}$$

This, across a 350 ohm bridge will generate

$$7.5 \times 10^{-8} \times 3.5 \times 10^{2} = 26.2 \text{ microvolts,}$$

which will, again at a 1% unbalance, result in 0.26 microvolts rms or 0.74 microvolts peak-to-peak at the output.

The foregoing discussion points up the fact that high impedance to ground is of at least equal importance with output-to-line isolation. Too little emphasis is often placed on this, and some manufacturers neglect to specify this parameter.

The necessity for the tightest possible regulation and freedom from drift in the supply voltage of low-level transducers is too obvious to belabor. The Model KG 25-0.2 has been designed and developed with all of these requirements clearly in mind, and is representative of the present state of the art.

ISOLATION TRANSFORMER FOR STRAIN GAUGE POWER SUPPLIES

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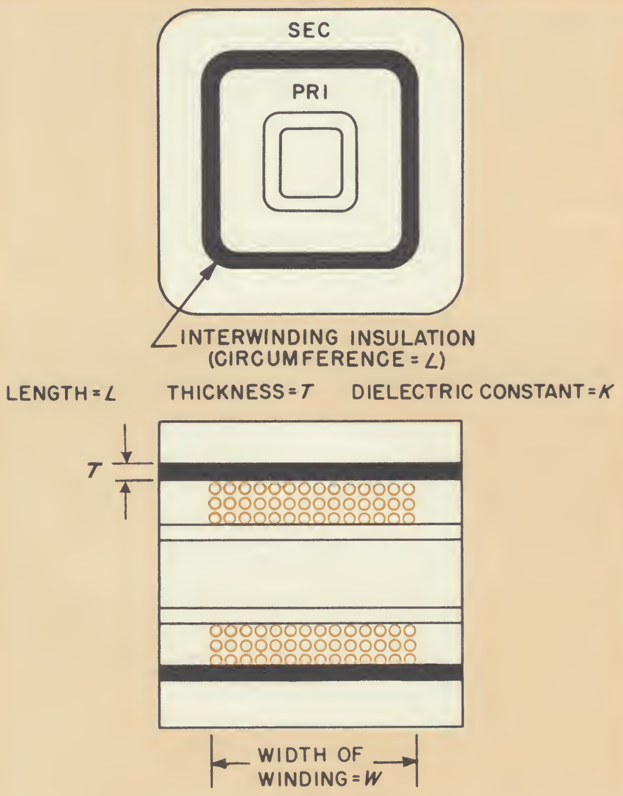
To gain some perspective into the nature of the problem, the characteristics of an ordinary transformer, such as the one used in a Kepco Model ABC Power Supply, may be used as a reference point. The effective input-to-output capacitance (C_X) of such a transformer is of the order of 600 pf. The secondary-to-ground capacitance (Cg) approximates 100 pf, and the insulation resistance may be as high as 400,000 megohms. However, the insulation resistance of most organic materials becomes halved for every 6°C increase in temperature. If such material is used in a transformer, the initial 400,000 megohm insulation resistance may decrease to as little as 100 megohms, at internal temperatures of 90°C (typical for a 50°C ambient rating).

A conventional transformer comprises a coil consisting of concentric primary and secondary windings. The mutual capacitance (C_X) between these windings can be appreciated by reference to Figure 1.



CAPACITANCE $= K\frac{A}{T}$ WHERE $A = WL$

FIGURE 1

The area occupied by the last layer of the primary winding, and the first layer of the secondary form the equivalent of a two-plate capacitor, separated by the interwinding insulation. Three methods offer reduction of the interwinding capacitance:

a) increase "T".

b) decrease "K", or

c) decrease "A".

Increasing "T" is practical for a reduction of about one order of magnitude. Beyond this point the transformer becomes impracticably large. Also, the leakage inductance increases to a point where the electrical performance is affected.

"K", the dielectric constant of the impregnated paper between the windings, has value of 2.5 to 3.0. By making the primary and secondary coils self-supporting, the dielectric becomes principally air, and "K" approaches 1.0. This makes possible a reduction of 2.5 to 3.0 times.

A reduction in the value of "A" is not practicable. Since the volume of the coil windings is fixed by the number of turns and required wire sizes, any reduction of "W" will necessitate an increase in "L", and vice versa. Therefore, no appreciable advantage can be gained in this area.

The next logical step is to interpose a grounded electrostatic shield between the primary and secondary windings. This effectively increases the capacity between primary and ground, and between secondary and ground, but is effective in greatly reducing the capacitance between primary and secondary. In the case of the Kepco ABC design power transformer, referenced above, the mutual capacitance was reduced from 600 pf to 10 pf, but the secondary-to-ground capacitance increased from 100 pf to 400 pf.

It is apparent that a radical departure from conventional design is necessary to achieve the desired characteristics. Figure 2 is a semi-schematic representation of such an assembly, which has been adopted in the new Kepco Model KG Transducer Power Supply.

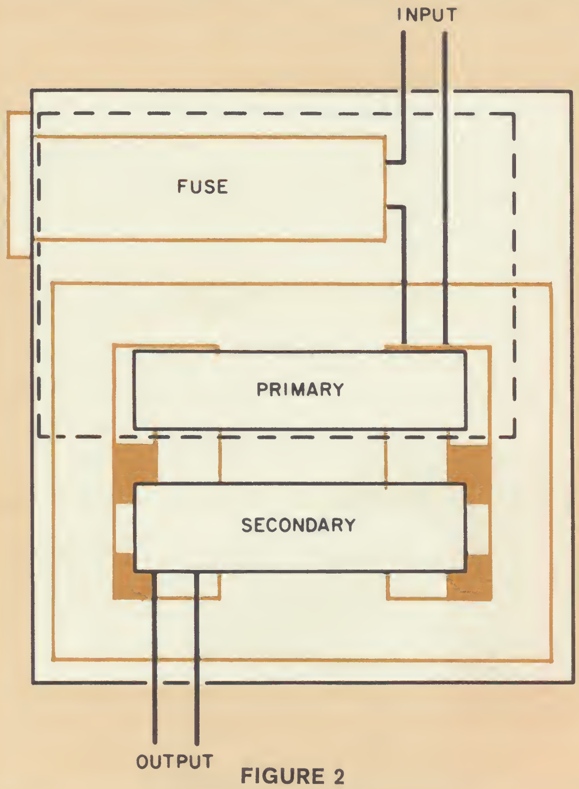


FIGURE 2

The salient features of this special transformer are as follows:

1. The primary and secondary coils are wound in two separate, narrow "pies", minimizing the areas over the core, and the areas facing each other. This minimizes the capacitance between windings as well as the capacitance to core.
2. The primary winding, including the fuse, is completely contained in its own electrostatic shield. This not only minimizes mutual capacitance, but virtually eliminates capacitance between the fuse, its wiring, and the output.
3. The secondary coil is liberally spaced from the primary winding, as well as the core and adjacent surfaces. This not only further attenuates the mutual capacitance, but reduces the secondary-to-ground capacitance.
4. In order to provide the necessary insulation resistance at 90°C (interior temperatures), nonorganic Teflon is used as the insulating medium. This material has superior insulation resistance, which it retains at elevated temperatures. Since its dielectric constant is rather high ($\cong$2.5), a shell construction is employed which supports the secondary coil at a minimum number of points. This leaves air (dielectric constant $\cong$ 1.0) to fill most of the space.
5. The entire assembly is surrounded by a case which provides magnetic, as well as electrostatic, shielding, effectively reducing pickup of stray fields in the secondary coil.
6. The design of the transformer case and its terminals provide exceptionally short (pin) wiring from the various transformer windings to a printed circuit (PC) board. Short leads of approximately 1″ are used to the AC connector giving complete separation of primary and secondary wiring. In addition, the location of the transformer on the power supply's main circuit board serves to enhance the shielding and isolation of the supply output.

Typical performance characteristics of the final production transformers are as follows:

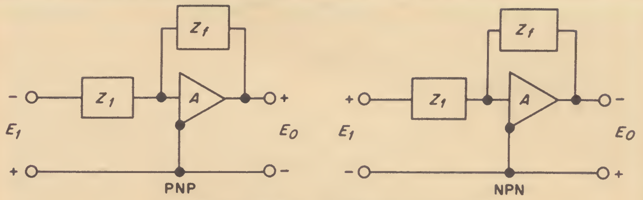
Effective input-to-output capacitance (C_X): 0.03-0.08 pf.
Effective secondary-to-ground capacitance (Cg): 20-35 pf.
Secondary-to-ground resistance (Rg): 200 K - 250K megohms (at 90°C).

When installed in the power supply, with its own unavoidable capacitances and leakage paths, the required specifications are met with a comfortable margin of safety.

At Kepco, each magnetic component requirement is treated as an integral part of the circuit design problem, with the Circuit Design and Magnetic Design groups working closely together. Many unique solutions result from this ability to shape circuit performance by tailoring the electrical and mechanical characteristics of the magnetic components. The Kepco KG 25-0.2 Strain Gauge Power Supply is an outstanding example of the advantages to be gained from this integrated design approach.

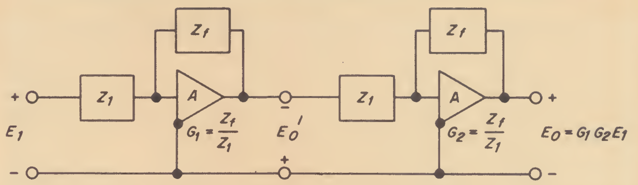
COMPLEMENTARY PROGRAMMING

The use of PNP pass elements in the Kepco PAX module group, with NPN transistors used as the pass in PBX modules (their sister group), opens an area of interconnection hitherto not feasible. Operationally, PNP elements require a negative common with a positive output while NPN elements result in a positive common terminal and negative output.



OPERATIONAL CONFIGURATION

The fact that the polarity of E_0 from one kind of module matches the requirement for E_1 (input) to its complement, permits the use of cascade circuits in special application.



NON INVERTING AMPLIFIER PAIR

NEW 52 PAGE 1966 KEPCO CATALOG

Detailed specifications of more than 320 standard Kepco Regulated Power Supplies together with much useful power supply information are contained in Catalog B-663. Write for your copy to Kepco, Inc., Publications Dept., 131-38 Sanford Avenue, Flushing, N.Y. 11352.

SHOW VAN USED BY NACO

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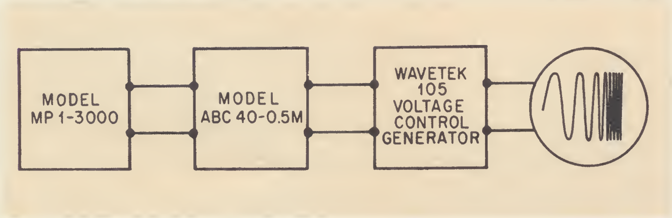
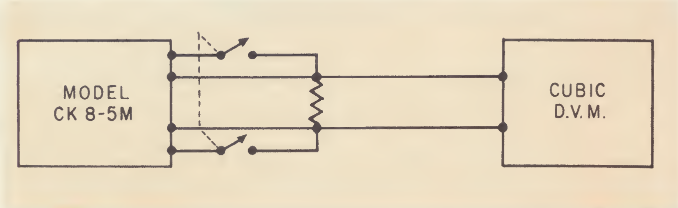
Kepco's representative in Upstate New York, NACO Electronics, finished a very successful 2 month mobile demonstration van tour of the upstate area in December. The Mobile Demonstrator visited such facilities as IBM, GE, Sylvania, Bell Aerosystems, General Dynamics, Xerox, Westinghouse, Griffiss AFB, Univac and many colleges and universities located in the Upstate New York area. On board were many representative power supplies manufactured by Kepco, Inc. as well as products of other manufacturers they represent.

By using the remote programming capability of the Kepco power supplies, one demonstration explained the versatility of this programming capability by electronically varying the frequency of a Wavetek function generator as a function of this programmed voltage change.



Another demonstration illustrated the importance of remote error sensing at the power supply load. Without the Remote Error sensing capability of the Kepco power supplies, the voltage variation at the load would include the voltage drop in the long wire leads to the load. By the use of the error sensing capability, however, the load was effectively placed at the output terminals of the power supply electrically thus, in effect, eliminating any voltage drop from the power supply to the load. By switching the error sense leads in and out of the circuit, the load lead drop was observed on a DVM.



Still another demonstration showed the ability of a Kepco power supply to maintain a constant speed of a motor as the load on the motor was changed. In this demonstration a tachometer output was fed back to the power supply which in turn decreased or increased the output voltage from the supply in order to maintain a constant speed of the motor under a varying load.

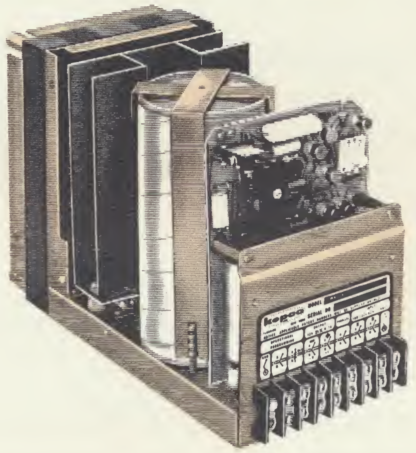
Other demonstrations showed the versatility of the "VIX"® (Automatic Voltage-Current Crossover) of the power supplies. In demonstrating this feature, a current limit control was set on the Kepco Model CK-8-5M with a constant load value (R). The voltage would be increased until the maximum current was reached. At this point, the power supply automatically changed to its constant current mode, and became a current regulated power supply. At the same time the "VIX" indicator lights showed the operator he was in the current mode rather than the voltage mode. The output of the VIX Indicators were then used to close a relay and actuate an alarm light. This also demonstrated the use of a power supply to control external devices in many industrial applications.

NEW KS DESIGN GROUP POWER SUPPLIES

MODEL KS 120-1M

The range of output voltage available in the KS Design Group of Kepco voltage/current regulated power supplies has been doubled by the recent availability of the KS 120-1M, KS 120-2.5M, KS 120-5M and KS 120-10M models. These supplies with 0.005% line regulation and 0.01% load regulation combined with other important features of the KS series such as automatic voltage/current crossover, VIX signal mode indicators (which visually indicate whether the power supply is regulating in voltage or current mode), and 10 turn controls for both current and voltage make these new KS supplies an important addition to this outstanding design group engineered and manufactured by Kepco.

NEW PWR POWER MODULES BY KEPCO



The unique protective current cutoff characteristics of the Kepco PWR modules make them especially useful in applications requiring circuit safety. These power supplies, when heavily overloaded or short circuited, automatically reduce output current to a small fraction of maximum ratings. When the overload is removed, however, PWR units immediately return to normal operation.

The complete story of this unusual and most useful design group was carried in Kepco Power Supply News Vol. 7 No. 146-1128.

Particularly aimed at the microcircuit field and other low voltage applications, two new models have just been announced, namely, the PWR4-14 and PWR7-11 providing 0-4 volts at 0-14 amperes and 0-7 volts at 0-11 amperes respectively. These are highly regulated power modules rated at 0.005% line and 0.05% load regulation. They are fully programmable[1] in voltage or current modes with external sensing. The design is based on the Kepco patented Flux-O-Tran line regulating transformer and fully transistorized bridge regulator, also a Kepco patented feature.

A further addition to the line is the PWR 36-3 providing 0-36 volts at 0-3 amperes. This unit also possesses all the features and characteristics of the PWR Design Group as set forth above.

Complete specifications and descriptions of these and more than 320 standard model Power Supplies are detailed in the new Kepco Catalog B-663 and available on request. Write: Kepco, Inc., Dept. PS, 131-38 Sanford Avenue, Flushing, N.Y. 11352.

[1] When programmed for less than the rated voltage (±5%), current rating reduces proportionally.

TOP KEPCO ENGINEERS SERVE AT IEEE

Kepco Display Host to Thousands of Engineers

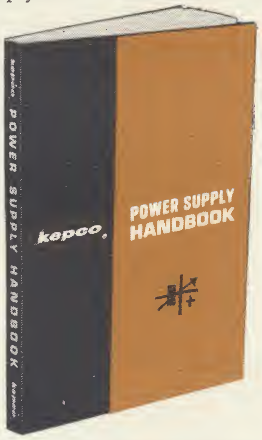
Kepco's General Manager, Mr. Max Kupferberg, reports that Kepco will once again play host to visiting electronic engineers at the New York IEEE Meeting.

The Kepco show booth itself is a spectacularly attractive design which has had favorable comment wherever shown. The arched backdrop, designed by FUNCTIONAL DISPLAYS, of Amityville, New York, is a handsome yet practical format for the presentation of Kepco Power Supplies and instruments.

Some twenty models will be on display representing the more than 320 different power supply models presently available. A new 1966 catalog will be distributed and visitors may register for a complimentary copy of the Kepco Power Supply Handbook. Of greater importance is the fact that this unique display will be continuously manned by the highest level engineering personnel for consultation and assistance on application problems.

THE KEPCO POWER SUPPLY HANDBOOK

Note: The response to the offer of the Kepco Power Supply Handbook carried in the last issues of Kepco Power Supply News has been so great that we are repeating it this month for those who may have missed it.



Regular readers of the Kepco Power Supply News have become familiar with the many unconventional power supply applications that have been evolved over the years. Beyond the classic job of powering other circuits, Power Supplies are increasingly finding application as instruments in their own right. This field has grown so in the past few years that we have undertaken to publish a Handbook covering the more interesting and useful power supply applications.

The Kepco Power Supply Handbook, written by Paul Birman, Kepco's Application Engineer, covers the subject of regulated DC Power Supplies in detail. Particular emphasis is placed on the programming concept and its myriad applications to complex systems control problems.

Profusely illustrated with innumerable circuit diagrams, block diagrams and photographs, the Kepco Power Supply Handbook is a valuable addition to any engineering library. For a complimentary copy, contact your closest Kepco representative or write on your company's letterhead to: Publications Manager, Dept. K Kepco, Inc., 131-38 Sanford Avenue, Flushing, New York 11352.

GLOSSARY OF POWER SUPPLY TERMS

The new Kepco Power Supply Handbook contains a Glossary of Power Supply Terms adding 29 new definitions to the already comprehensive list previously published by Kepco. Here are some of these new terms and their definitions:

FILTERS:
Filters are RC or LC networks arranged as low pass devices to attenuate the varying component that remains when a-c voltage is rectified. In power supplies without subsequent active series regulators, the filters determine the amount of ripple that will remain in the d-c output. In supplies with active feedback series regulators, the regulator mainly controls the ripple with output filtering serving chiefly for phase-gain control as a *lag* element.

FLUX-O-TRAN:®
A registered trademark of Kepco, Inc., applied to ferro-resonant voltage regulating transformers of a special design, which are used in many proprietary designs. The Flux-O-Tran, with its resonating capacitor provides a squarewave output (for higher rectifier and filter efficiency) whose magnitude is largely independent of the primary voltage amplitude.

LAG NETWORKS:
Resistance-reactive components, arranged to control phase-gain rolloff versus frequency. Used to assure the dynamic stability of a power supply's comparison amplifier. The main effect of a lag network is a reduction of gain at relatively low frequencies so that the slope of the remaining rolloff can be relatively more gentle.

LEAD NETWORKS:
Resistive-reactive components arranged to control phase-gain rolloff versus frequency. Used to assure the dynamic stability of a power supply's comparison amplifier. The main effect of a lead network is to introduce a phase lead at higher frequencies, near the unity gain frequency.

LOOP (LEAKAGE) CURRENT:
A d-c current flowing in the feedback loop (voltage control) independent of the control current generated by the reference zener diode source and reference resistor. The loop (leakage) current remains when the reference current is made zero. It may be compensated for, or nulled in special applications to achieve a very high impedance (zero current) at the feedback (voltage control) terminals.

LOOP GAIN:
A measure of the feedback in a closed-loop system, being equal to the ratio of the open-loop to the closed-loop gains, in db, A—G. The magnitude of the loop gain determines the error attenuation and, therefore, the performance of an amplifier used as a voltage regulator. (*See* Open-loop and Closed-loop gain.)

MTBF Mean time between (or before) failure:
A measure of the reliability giving either the time before first failure or, for repairable equipment, the average time between repairs. MTBF may be approximated or predicted by summing the reciprocal failure rates of individual components in an assembly.

In place of the overworked term "ripple", and instead of the recently proposed acronym "PARD" (Periodic And Random Deviation), Kepco proposes a new term: CRUD . . . **C**ontinuous & **R**andom **U**nwanted **D**eviation. CRUD has mnemonic advantages over other terms, and in addition specifies that ripples be restricted to *unwanted,* as distinguished from wanted periodic or random waveforms . . . *What do our readers think?*